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FORESTRY SCIENCE

# Genetic diversity and correlation between morphological traits of pequi fruits (*Caryocar brasiliense* Camb.) with and without thorns at the endocarp

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**Abstract:** Morphological characteristics of pequi fruits (*Caryocar brasiliense*) allows us to obtain information for the conservation, breeding, and detect genetic variability. Thus, the aims of this research were to characterize the genetic diversity of *Caryocar brasiliense* that produce fruits with and without thorn at the endocarp; determine the important characters in the study of genetic diversity, and to estimate phenotypic and genotypic correlations. 80 fruits with thorns and 90 fruits without thorns were evaluated. Data were used for analysis: Euclidian distance as a measure of dissimilarity and the Tocher method for delimitation of groups; Principal Component Analysis, and genotypic and phenotypic correlations. Genetic dissimilarity of *C. brasiliense* ranged from 0.066 (B6-D6) to 0.908 (A14-B3). Tocher method allowed dividing the matrices into three groups, the dendrogram into five groups, and the principal components allowed the distribution in 8 groups. We observed 15 significant correlations for characters of fruit with thorns and 31 correlations for characters of fruit without thorns. The weight of the fruit (with thorns) and the pyrene yield (without thorns) are relevant correlations for production. The groupings generated allowed the classification of the matrices into distinct sets. Allowed the identification of potential producers plants that could be used in breeding programs.

**Key words:** *Caryocar brasiliense*, conservation, genetic breeding, multivariate analysis, quantitative traits, Savanna.

## INTRODUCTION

The genetic variability in plant species can be observed within a population or between populations of the same species. This diversity explains the relevance of studying methods of conservation and sustainable management of native species (Ribeiro & Rodrigues 2006). The distinct morphological characteristics are common in native plants of the Brazilian cerrado (savanna vegetation) even between fruits of the same area, indicating that the region of occurrence of the fruits is an important factor in the variability of the evaluated characters (Corrêa et al. 2000, Silva et al. 2001). The characterization of the fruits about their physical aspects allows them to obtain information that can be used in the determination of genetic variability, quality parameters, yield, and breeding programs (Oliveira et al. 2009).

The pequi tree (*Caryocar brasiliense*) is a native plant of cerrado, whose exploitation occurs in the extractive way. Therefore, the supply of fruits of this species can be put at risk, either by the continuous collection of fruits or

by the non-replenishment of matrices on the environmental. In this perspective the creation of germplasm banks for the preservation of genetic variability becomes fundamental. Also, the genetic improvement of the species supports the creation and stimulation of investments in commercial crops, from the development of new genotypes that add favourable characteristics to the crop, as well as on environment and industrial yield and organoleptic characteristics.

The pequi (Figure 1) has many applications include human food, medicinal use, in the production of cosmetics, and production of biodiesel. Scientific research with pequi widely found in nature, that is, with plants that produce fruit with thorns at the endocarp is incipient, however, Brazil is still a highlight when compared to other countries. Most research evaluated on its economic importance and characterization of plants and fruits with thorns at the endocarp (Silva et al. 2012, Giordani et al. 2012, Moura et al. 2013, Nascimento-Silva & Naves 2019, Pinto et al. 2016, Roll et al. 2018). Studies with *C. brasiliense* that produces fruit without thorns at the endocarp is too little (Gomes et al. 2019, Londe et al. 2010). A single *C. brasiliense* plant that does not produce thorns at the endocarp was reported by Kerr et al. (2007) in São José do Xingu – MT, Brazil. Pequi fruits without thorns have peculiar characteristics about fruits with thorns. The fruits without thorns are light yellow, fleshier and have a higher water content than fruits with thorns, also have a taste and smell sweet (Gomes et al. 2019).

The information as weight, size of fruits and seeds, and the number of seeds per fruit are characteristic of each species, with high influence of the environment (Alves et al. 2005). Due to the variability of morphological characters in the tree species, the analysis of fruits through physical and chemical characters allows differentiate the individuals of a population (Cruz & Carvalho 2003, Melo et al. 2001) and species of the same genus (Cruz et al. 2001), besides the classification of ecological groups, characterization of germplasm (Alves et al. 2003) and many other applications. Because of the individual variation there is the

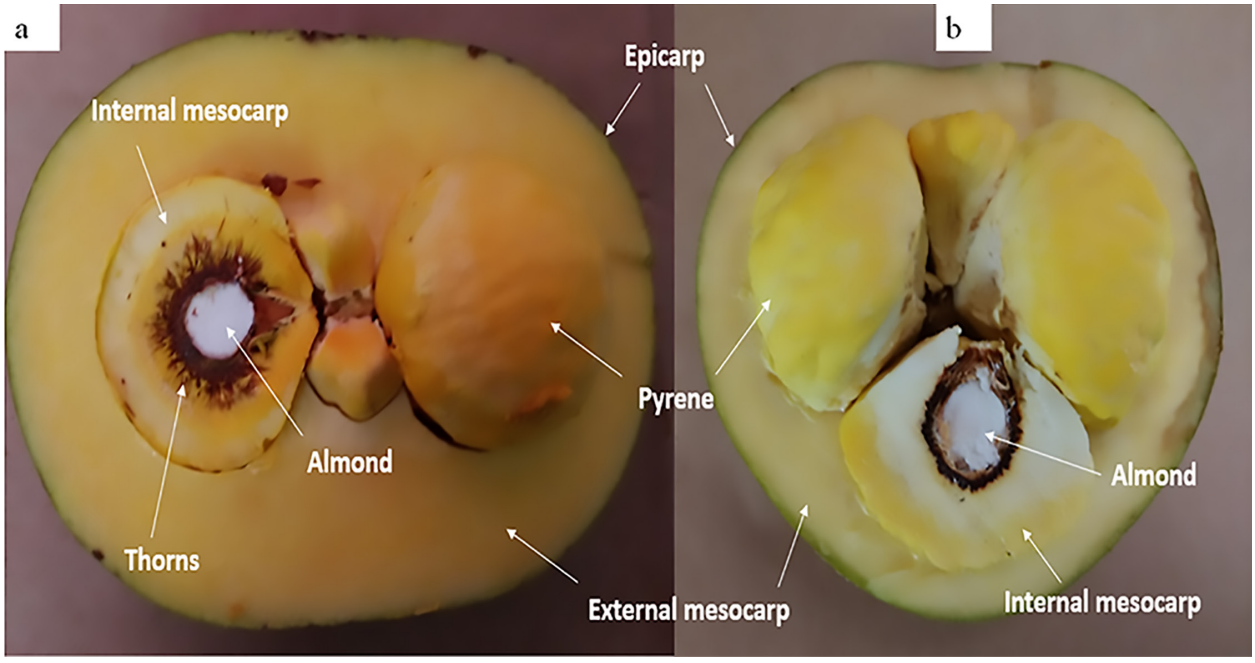


**Figure 1.** Morphological aspects of pequi (*Caryocar brasiliense*). a: with thorns, and b: without thorns.

possibility of a selection of progenies aiming at the improvement of some characteristics of commercial interest. Seeds, because they are reproductive organs, have great stability to the vegetative characters, due to the greater genetic control and the selection pressure exerted during the evolutionary process (Alves et al. 2010). The patterns of genetic variation that occur between and within the population allow the selection, conservation, and management techniques appropriate, especially about populations of natural occurrence.

The study of diversity and genetic structure in populations of *C. brasiliense* is important to understand how this diversity is distributed and what are the characteristics of the environment or species that influence genetic diversity. In the establishing a *C. brasiliense* improvement program, germplasm evaluation is essential to understand the gene pool and the genetic value of the available germplasm. Genetic variability is essential for plant breeding, in which selection acts to develop superior genotypes (Bhandari et al. 2017). The greater the variation present for a character in breeding germplasm, the greater the scope for improvement through selection. Considering the importance of the species, this work aimed to characterize the genetic diversity *C. brasiliense* producers of fruits with and without thorn at the endocarp through the physical characteristics of fruits; determine the important characters in the study of genetic diversity, and to estimate phenotypic and genotypic correlations of physical traits of *C. brasiliense* fruits from matrices producing fruit with and without thorn at the endocarp.

## MATERIALS AND METHODS

### Study area

The present study was carried out between November 2017 and June 2018 in a pequi tree (*Caryocar brasiliense*) orchard, at the experimental farm "Água Limpa" (19°6'16,49"S and 48°20'54,38"W), belonging to the Universidade Federal de Uberlândia (UFU), Uberlândia-MG, Brazil. The daily temperature at the site ranged between 17 ºC and 33 ºC. According to Köppen classification, the area is characterized as Aw (tropical, hot humid area with cold and dry winter) with an altitude of 795 m.

### Population sampling

The plants for collection included 8 fruit trees with thorns (Group 1 - A8, B7, D14, B3, B25, B6, B13, and D6) and 9 fruit trees without thorns (Group 2 - C10, C9, B20, A14, B26, C6, A17, B29, and D8). The multivariate analysis consisted of a set of 17 matrices producing fruits with and without thorns (4 fruits with 1 pyrene, 4 fruits with 2 pyrene and 2 fruits with 3 pyrenes, in each matrix). The observed quantitative characters were: (i) Fruit Weight (g), (ii) Height Fruit (mm), (iii) Fruit Length (mm), (iv) Fruit Width (mm), (v) Pyrene Height (mm), (vi) Pyrene Length (mm), (vii) Pyrene Diameter (mm), (viii) Pyrenes Weight (g), (ix) Peel Weight (g), (x) Peel Thickness (mm) and (xi) Pyrenes Yield (Figure 2). The measurements were performed using a manual caliper and a digital scale. The values of height, length, width, and diameter were measured in the median positions.

### Data analysis

The data obtained were analysed using of t-test for comparing means of two groups, at 0.05 probability level. Posteriorly were submitted to the dissimilarity analysis by the Euclidean distance and, later, the methods of Tocher (Rao 1952) and UPGMA (Unweighted Pair Group Method With Arithmetic Mean) were adopted to evaluate the grouping pattern of the matrices of *C. brasiliense*. To identify the patterns of morphological variation, principal component

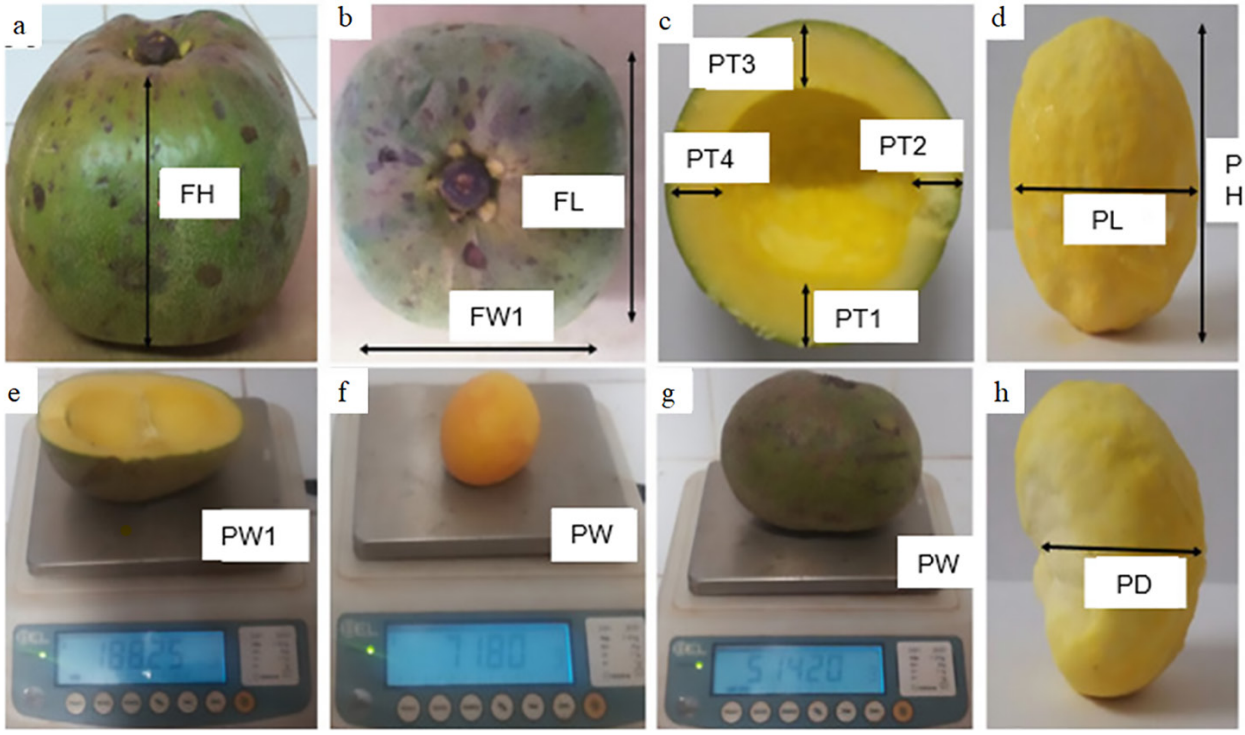


**Figure 2. Measurements in fruits of pequi (*Caryocar brasiliense*) with and without thorns at endocarp. (a) FH: Fruit Height (mm), (b) FL: Fruit Length (mm), FW1: Fruit Width (mm), (c) PT1, PT2, PT3 and PT4: Peel Thickness, (d) PL: Pyrene Length (mm), PH: Pyrene Height (mm), (e) PW1: Peel Weight (g), (f) PW: Pyrenes Weight (g), (g) PW: Pyrenes Weight (g), (h) PD: Pyrene Diameter (mm).**

analysis (PCA) was conducted. The PCA was used to determine to what extent each of the eleven variables contributed to the total measured variation. It was used the Singh (1981) criterion to quantify the relative contribution of these traits to genetic divergence. Analysis of phenotypic and genotypic correlations was performed according to Cruz et al. (2012). The data processing was performed using the statistical program Computational Program in Genetics and Statistics software - GENES (Cruz 2016).

## RESULTS

The mean values for the 11 variables analyzed in fruits of *C. brasiliense* fruits with and without thorns in the endocarp are shown in table I. There are differences between the two groups of pequi trees for all variables, and the group of plants that produce fruits without thorns has significantly higher means ($p \leq 0.05$), except for the variables pyrene diameter (PD) and yield pyrene (YP).

In this study, the genetic dissimilarity expressed by the Euclidean distance between the 17 matrices of pequi fruit producers with and without thorns varied from 0.066 to 0.908 between the matrices B6-D6 and A14-B3, respectively, demonstrating the high genetic diversity between the accessions (Table II). The Tocher method allowed the division of the matrices into three groups (Table III). It was observed that group I had the highest number of matrices, including genotypes producing pequi with and without thorns; groups II and III present only two matrices each, and in group III fruit trees without thorns were concentrated only.

**Table I. Mean values for the eleven variables measured in fruits of *Caryocar brasiliense* with and without thorns in the endocarp, cultivated at Água Limpa Experimental Station - UFU, Uberlândia, MG, Brazil.**

| Variable | Group with thorns | Group without thorns |
|---|---|---|
| FW | 394,50b | 504,61a |
| HF | 77,42b | 85,55a |
| FL | 98,48b | 104,62a |
| FW | 78,40b | 87,92a |
| PH | 57,55b | 63,60a |
| PL | 45,61b | 46,75a |
| PD | 41,00a | 39,17b |
| P1W | 69,52b | 71,41a |
| P2W | 277,66b | 382,64a |
| PT | 13,70b | 18,66a |
| YP | 0,20a | 0,17b |

**FW – Fruit Weight; HF – Height Fruit; FL – Fruit Length; FW – Fruit Width; PH – Pyrene Height; PL – Pyrene Length; PD – Pyrene Diameter; P1W – Pyrenes Weight; P2W – Peel Weight; PT – Peel Thickness; YP – Yield Pyrenes. Means followed by the same letters in the row do not differ by t-test, at 0.05 probability level.**

To analyse the grouping pattern of the individuals of pequi tree, the UPGMA (Unweighted Pair Group Method with Arithmetic Mean) method was adopted, which allowed the generation of the dendrogram. The cophenetic coefficient was 0.83, significant by the t-test ($p \leq 0.01$) indicating an adequate graphical representation of the distances since it was higher than 0.7 as suggested by Cruz et al. (2011). By adopting a cut of 50% of the genetic distance, in a position in which a high-level change in the figure was observed, as suggested by Cruz et al. (2012), the dendrogram showed the matrices distributed in five groups (Figure 3). The matrices B29 and D8 (both fruit producers without thorns) constituted individual groups, revealing their potential breeding futures.

Results from the PCA indicated that more than 90.65% of the variability observed can be explained by the first two components (Table IV). The graphic dispersion in the two-dimensional space revealed the formation of eight groups of pequi fruit producers with and without thorns in the endocarp (Figure 4). Like the clustering pattern obtained by the UPGMA method, matrices B29 and D8 were isolated in individual groups. The relative contribution of each character to the genetic divergence is shown in Table V. It can be verified that the character's fruit mass and bark mass were the most important for genetic diversity, contributing with 53.24% and 45.60%, respectively.

The dispersion of the genotypes by principal component analysis was graphically represented (Figure 4) to be compared to the groupings by the UPGMA (Figure 1) and Tocher (Table III) methods and evaluate the influence of each feature in the genetic diversity. Relative contributions of each feature of the genetic divergence are shown in Table V. Other features also presented estimates of the relative contribution of small magnitude showing small expression in the genetic divergence.

Table VI are the genetic and phenotypic correlations for the characters evaluated in fruits of *C. brasiliense* with and without thorns in the endocarp. We observed the occurrence of 15 significant correlations by t-Test ($p \leq 0.05$) for characters of pequi fruit with thorns in the endocarp and 31 significant correlations by t-Test ($p \leq 0.05$) for fruits characters of pequi thorns in the endocarp (Table VI). These results indicate a high degree of association among some evaluated characters. Genotype correlations above 0.70 are considered high, but it is possible to perform indirect selection when they are above 0.50. Correlation coefficients were found to be zero among some of the characters studied (Table VI) in fruits of *C. brasiliense* with thorns in the endocarp. However, this does not show a lack of relationship, but rather the absence of a linear relationship between them (Cruz et al. 2012).

**Table II.** Genetic dissimilarity matrix based on the Euclidean distance of the 17 trees of *Caryocar brasiliense* with and without thorns at the endocarp, cultivated at Água Limpa Experimental Station - UFU, Uberlândia, MG, Brazil, 2017/2018.

| Trees | B7 | A8 | B13 | B25 | B3 | D6 | D14 | B29 | A14 | C9 | B26 | B20 | C10 | A17 | C6 | D8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B6** | 0.368 | 0.372 | 0.144 | 0.219 | 0.161 | 0.066 | 0.177 | 0.774 | 0.220 | 0.286 | 0.328 | 0.324 | 0.247 | 0.398 | 0.348 | 0.526 |
| **B7** | | 0.600 | 0.351 | 0.287 | 0.327 | 0.323 | 0.220 | 0.562 | 0.311 | 0.208 | 0.599 | 0.163 | 0.227 | 0.201 | 0.232 | 0.374 |
| **A8** | | | 0.323 | 0.325 | 0.335 | 0.373 | 0.408 | 0.763 | 0.321 | 0.469 | 0.145 | 0.507 | 0.460 | 0.555 | 0.473 | 0.554 |
| **B13** | | | | 0.151 | 0.175 | 0.105 | 0.161 | 0.726 | 0.193 | 0.277 | 0.322 | 0.273 | 0.243 | 0.375 | 0.323 | 0.484 |
| **B25** | | | | | 0.129 | 0.184 | 0.135 | 0.605 | 0.098 | 0.193 | 0.350 | 0.211 | 0.188 | 0.279 | 0.214 | 0.370 |
| **B3** | | | | | | 0.152 | 0.156 | 0.665 | 0.908 | 0.184 | 0.318 | 0.260 | 0.167 | 0.300 | 0.231 | 0.414 |
| **D6** | | | | | | | 0.133 | 0.736 | 0.194 | 0.246 | 0.342 | 0.272 | 0.208 | 0.356 | 0.310 | 0.488 |
| **D14** | | | | | | | | 0.628 | 0.163 | 0.179 | 0.400 | 0.192 | 0.164 | 0.264 | 0.225 | 0.395 |
| **B29** | | | | | | | | | 0.592 | 0.551 | 0.803 | 0.534 | 0.587 | 0.448 | 0.478 | 0.270 |
| **A14** | | | | | | | | | | 0.155 | 0.318 | 0.222 | 0.155 | 0.255 | 0.185 | 0.340 |
| **C9** | | | | | | | | | | | 0.456 | 0.143 | 0.073 | 0.139 | 0.106 | 0.301 |
| **B26** | | | | | | | | | | | | 0.510 | 0.440 | 0.555 | 0.472 | 0.576 |
| **B20** | | | | | | | | | | | | | 0.137 | 0.138 | 0.158 | 0.308 |
| **C10** | | | | | | | | | | | | | | 0.167 | 0.138 | 0.334 |
| **A17** | | | | | | | | | | | | | | | 0.120 | 0.218 |
| **C6** | | | | | | | | | | | | | | | | 0.243 |

**Table III.** Tocher grouping obtained from the average Euclidean distance standardized on 17 trees for the 11 characters of the fruits, produced at Água Limpa Experimental Station - UFU, Uberlândia - MG, Brazil, 2017/2018.

| Group | Tress |
|---|---|
| I | B6 D6 B13 D14 B3 B25 A14 C10 C9 B20 C6 A17 B7 |
| II | A8 B26 |
| III | B29 D8 |

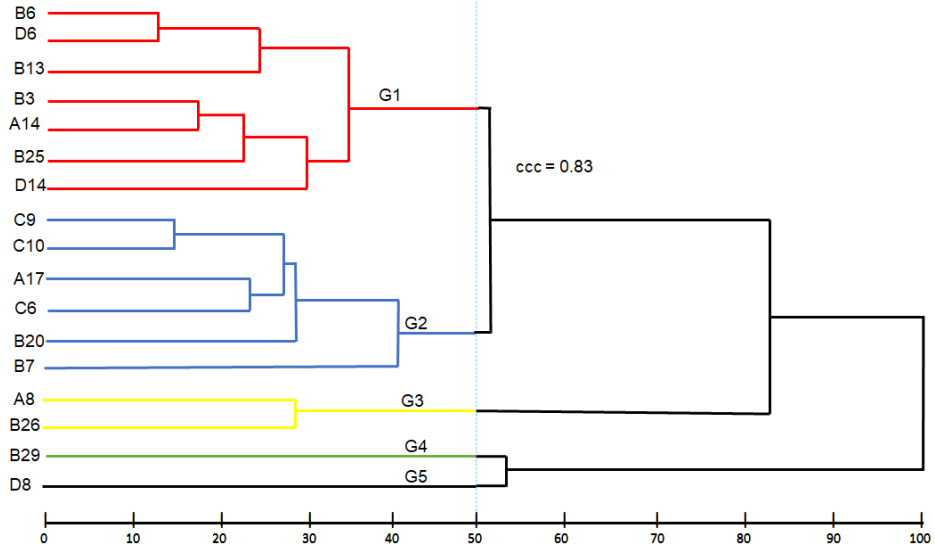


**Figure 3.** Dendrogram of the analysis of the 17 matrices of pequi tree by Unweighted Pair Group Method with Arithmetic Mean (UPGMA) obtained from the average Euclidean distance standardized for the eleven morphological characters of the fruits. CCC: Coefficient cophenetic correlation. Água Limpa Experimental Station - UFU, Uberlândia - MG, Brazil, 2017/2018.

**Table IV.** Estimates of the eigenvalues associated to the main components and their percentage and cumulative variance of 11 morphological characters in *C. brasiliense*, produced at Água Limpa Experimental Station - UFU, Uberlândia - MG, Brazil, 2017/2018.

| Principal Component | AutoValue | Variance (%) | Acumulative variance (%) |
|---|---|---|---|
| 1 | 0.98 | 63.43 | 63.43 |
| 2 | 2.99 | 27.22 | 90.65 |
| 3 | 0.48 | 4.42 | 95.07 |
| 4 | 0.20 | 1.87 | 96.94 |
| 5 | 0.16 | 1.46 | 98.41 |
| 6 | 0.09 | 0.81 | 99.22 |
| 7 | 0.041 | 0.37 | 99.60 |
| 8 | 0.20 | 0.18 | 99.78 |
| 9 | 0.17 | 0.16 | 99.94 |
| 10 | 0.05 | 0.050 | 99.99 |
| 11 | 0.0004 | 0.0043 | 100.0 |

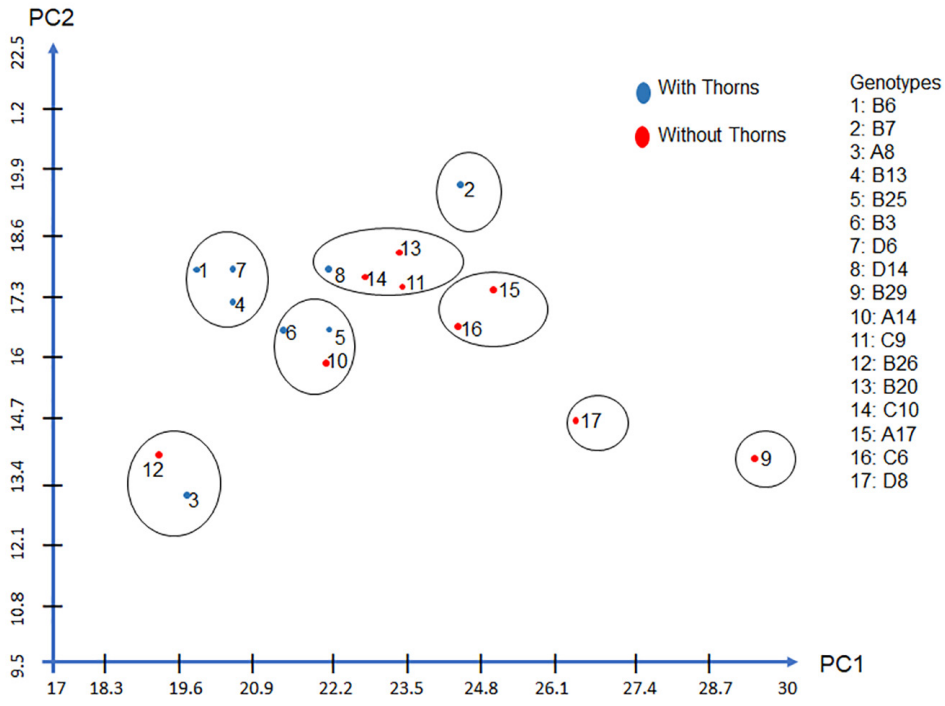


**Figure 4.** Graphical dispersion of the 17 matrices of *Caryocar brasiliense* using the first two main components obtained with eleven morphological characters of the fruits, produced at Água Limpa Experimental Station - UFU, Uberlândia - MG, Brazil, 2017/2018.

## DISCUSSION

The genetic variation within populations in relation to variation between them is observed in many species of plant for different phenotypic characteristics (Adhikari et al. 2018, Adjebeng-Danquah et al. 2016, Ibukun & Yomi 2020, Gadissa et al. 2020, Hassanein & Al-Soqeer 2018, Yulianah et al. 2020). In the present study, we attempted to analyse the genetic diversity of *C. brasiliense* that produces fruits with and without thorns at the endocarp by morphological traits of fruits. The characterization and quantification of the genetic diversity of a germplasm bank are essential to define strategies to increase the genetic base of the collection in conservation,

**Table V. Relative contribution of the morphometric characteristics of *Caryocar brasiliense* fruits with and without thorns in the endocarp to the divergence of Singh (1981).**

| Characteristics | S.j. | Percentage (%) |
|---|---|---|
| Fruit Weight | 5663818.04 | 53.24 |
| Fruit Height | 304437.66 | 0.28 |
| Fruit Length | 12015.36 | 0.11 |
| Fruit Width | 16996.70 | 0.15 |
| Pyrenes Height | 8304.26 | 0.08 |
| Pyrenes Length | 4258.84 | 0.04 |
| Pyrenes Diameter | 2272.27 | 0.02 |
| Pyrenes Weight | 46875.23 | 0.44 |
| Peel Weight | 4850628.67 | 45.60 |
| Peel Thickness | 4488.82 | 0.04 |
| Yield Pyrenes | 0.35 | 0.0 |

**S.j: Relative contribution for divergence of Singh (1981).**

as well as to define the use of germplasm for breeding purposes. In addition, the genetic diversity of matrices that produces fruits without spines using morphological markers is described here for the first time. The thorns in the fruits often cause accidents during consumption. The absence of thorns in the fruits can become attractive for the genetic improvement of the species. For this, it is necessary to study the genetic variability existing in the species and between different matrices.

In this study, when evaluating the means of the two groups of *C. brasiliense* through the t-test, it was found that there is a significant difference between the biometric attributes between the two groups. The group of *C. brasiliense* producers of fruits without thorns at the endocarp presents the highest values for the evaluated characters, except for pyrene diameter (PD) and yield pyrene (YP), evidencing the superiority of this group of plants in the population under study.

In populations of *C. brasiliense* that produce fruits with thorns, genetic diversity was found among the matrices based on physical characteristics of fruits, indicating the selection of matrices with the largest fruits and, among these, those whose fruits have thicker pulp (Santos et al. 2018). In the study by Soares et al. (2017) about the repeatability estimates of pequi fruits allowed to infer a high genetic control for the characteristics of total fruit weight; weight of the external mesocarp; average pyrene weight; average pulp weight; and lipid content and, therefore, a greater probability of expression of these characteristics in the clonal descendants of selected matrices.

In this study, the first two principal components explained almost 90% of the total variance contained in the set of evaluated features. Therefore, it is possible to satisfactorily access the observed variability among the genotypes and, under these circumstances, to interpret the phenomenon with considerable simplification through a two-dimensional graphical representation (Cruz et al. 2012). Genotypes were clustered into eight distinct groups, which partially agreed to the results obtained by the UPGMA method. Evaluation of the genotypic differences through clustering studies such as UPGMA, Tocher, and PCA is quite useful to the breeder while choosing the best parents. In the analyses carried out by Ramos & Souza (2011) in *Caryocar coriaceum*, the characteristics that were most important for the divergence among and within the population were the bark mass, with a contribution of 87.72% and fruit mass, with 8.91%, consistent with the results obtained in this research. The study of the correlations between characters allows the knowledge of the changes that occur in one character when the selection is made in another that is correlated to it. This information is useful to the breeder, especially when selecting for a character is hampered by low heritability or

**Table VI. Genetic correlations (below diagonal) and phenotypic correlations (above diagonal) between morphological characters of pequis with and without thorns in the endocarp, produced at Água Limpa Experimental Station – UFU, Uberlândia – MG, Brazil, 2017/2018.**

| | Pequi with thorns | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **FW** | **FH** | **FL** | **FW** | **PH** | **PL** | **PD** | **PW** | **PW1** | **PT** | **PY** |
| FW | | 0.9322** | 0.7311* | 0.6808 | 0.7034 | 0.6866 | 0.6950 | 0.7906* | 0.9776** | 0.6843 | -0.1027 |
| FH | 1.0000$^{++}$ | | 0.5598 | 0.6479 | 0.7018 | 0.6646 | 0.6665 | 0.4806* | 0.9010** | 0.6509 | -0.0781 |
| FL | --- | --- | | 0.5525 | 0.3895 | 0.3818 | 0.5660 | 0.4404 | 0.7715* | 0.6948 | -0.3820 |
| FW1 | --- | --- | -0.5385 | | 0.4666 | 0.7263* | 0.3540 | 0.5847 | 0.6627 | 0.6028 | -0.0823 |
| PH | 0.8747 | 0.7506 | --- | --- | | 0.9168** | 0.9112** | 0.9831** | 0.5490 | 0.0789 | 0.5737 |
| PL | 0.8334 | 0.7097 | --- | --- | 0.9423$^{+}$ | | 0.7740* | 0.9405** | 0.5417 | 0.1380 | 0.5396 |
| PD | 0.7985 | 0.6674 | --- | --- | 0.9379 | 0.7529 | | 0.8800** | 0.5608 | 0.0793 | 0.4402 |
| PW | 0.9769$^{+}$ | 0.8673 | --- | --- | 1.0000$^{++}$ | 0.9531 | 0.8931 | | 0.6510 | 0.2012 | 0.4830 |
| PW1 | 0.9695$^{+}$ | 0.9937$^{+}$ | --- | --- | 0.6151 | 0.6037 | 0.5726 | 0.7384 | | 0.8092* | -0.3054 |
| PT | 0.8183 | 0.7202 | --- | --- | -0.2340 | -0.0514 | -0.2633 | -0.0388 | 0.9881$^{++}$ | | -0.7425* |
| PY | 0.5655 | 0.1460 | --- | --- | 0.9756$^{+}$ | 0.8601 | 0.7691 | 0.7634 | 0.247 | -1.8227$^{++}$ | |
| **----------Pequi without thorns ----------** | | | | | | | | | | | |
| FW | | 0.9828** | 0.8896** | 0.9581** | 0.7672* | 0.1135 | 0.2920 | 0.4498 | 0.9933** | 0.9186** | -0.8363** |
| FH | 1.0000$^{++}$ | | 0.8523** | 0.9322** | 0.7109* | 0.0310 | 0.2116 | 0.3560 | 0.9902** | 0.9602** | -0.8421** |
| FL | 1.0000$^{++}$ | 1.0000$^{++}$ | | 0.9554** | 0.9506** | 0.4653 | 0.6541 | 0.7754* | 0.8392** | 0.7380* | -0.5007 |
| FW1 | 0.9896$^{+}$ | 0.9672 | 1.0000++ | | 0.8637** | 0.3573 | 0.4498 | 0.6274 | 0.9292** | 0.8441** | -0.6744* |
| PH | 0.8494 | 0.7298 | 1.0000$^{++}$ | 0.9299 | | 0.6141 | 0.7242* | 0.8710** | 0.6988* | 0.5515 | -0.3148 |
| PL | 0.1368 | 0.0188 | 0.7352 | 0.4001 | 0.6053 | | 0.7403* | 0.8591** | 0.0097 | -0.1154 | 0.3392 |
| PD | 0.3132 | 0.2029 | 0.9687$^{+}$ | 0.4887 | 0.7237 | 0.7449 | | 0.9176** | 0.1937 | 0.0379 | 0.2098 |
| PW | 0.5409 | 0.3709 | 1.0000$^{++}$ | 0.7244 | 0.8932 | 0.8764 | 0.9497 | | 0.3497 | 0.1911 | 0.0707 |
| PW1 | 0.9959$^{++}$ | 1.0224$^{++}$ | 0.9845$^{+}$ | 0.9568 | 0.7569 | 0.0131 | 0.1930 | 0.4049 | | 0.9459** | -0.8796** |
| PT | 0.9772$^{+}$ | 0.9818 | 0.9995$^{++}$ | 0.8930 | 0.5686 | -0.1395 | 0.0181 | 0.1843 | 0.9910$^{+}$ | | -0.8606** |
| PY | ---1.0000$^{++}$ | -1.0000$^{++}$ | -0.2566 | ---1.0000$^{++}$ | -0.7750 | 0.3738 | 0.2042 | -02367 | -1.0000$^{++}$ | -1.0000$^{++}$ | |

**FW: Fruit Weight (g), FH: Fruit Height (mm), FL: Fruit Length (mm), FW1: Fruit Width (mm), PH: Pyrene Height (mm), PL: Pyrene Length (mm), PD: Pyrene Diameter (mm), PW: Pyrenes Weight (g), PW1: Peel Weight (g), PT: Peel Thickness (mm) and PY: Pyrenes Yield. ** and * Significant at 1% and 5% probability by t test; $^{++}$ and $^{+}$ Significant at 1% and 5% by the Bootstrap method with 500 simulations.**

hindrance in its measurement and identification (Cruz et al. 2012).

Analysis of correlation coefficients was performed to find out the inter-relationship between the pairs of traits studied. Both genotypic and phenotypic pairwise correlation coefficients were presented in Table VI. The phenotypic correlation is estimated based on directly measured data and may be of the genetic or environmental cause. Our results suggest for most of the characters, the genotypic correlations were superior to the phenotypic ones and had the same direction for the characters of pequi fruit with or without thorns in the endocarp (Table VI). The groupings generated by the different methods allowed the classification of the matrices into distinct sets based on the genetic similarity evaluated from different fruit and pyrene characters. They also allowed the identification of potential producers that could be used in breeding programs of the species.

The selection gain for a breeding program that aims to produce fruits with a high amount of fruit pulp, the correlations are useful for the breeder to define the character that is under selection. In the selection process to select fruits with higher pyrene yield, a selection by

the mass of pyrenes is suggested, due to a high correlation between pyrene mass and fruit mass. About the fruit without thorns in all the characters analysed, the selection by the mass of the pyrene is indicated, as this correlates with the yield of the pyrene and the mass of the fruit (Table VI). In the pequi with thorns, when analysing the correlations between the characters it was also found that the selection by the mass of the pyrene is the most indicated. It should be noted that making the selection by the fruit mass would not be the best strategy because the fruit mass has no linear association with yield.

This study was conducted with a view to characterizing the genetic diversity of *C. brasiliense* by morphological traits of pequi fruits with and without thorns at the endocarp. The multivariate analysis of Tocher and UPGMA grouping carried out with Euclidean distance from physical characters of *C. brasiliense* fruits with and without thorns at the endocarp allowed to determine the genetic diversity similarly and allowed the identification of the most divergent and potential parents B3 and A14 matrices for a breeding program. The Fruit Weight and Peel Weight characters were the most important in determining the genetic diversity of *C. brasiliense* with and without thorns at the endocarp. The study revealed considerable phenotypical diversity among *C. brasiliense* genotypes. A high correlation was found between some traits, which could reduce the number of traits to be studied in *C. brasiliense* germplasm.

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